Plant

Colbert Station of Tennessee Valley Authority.

Type of Plant

Coal-fired electric power generation plant. 200 Mw capacity.

Emissions

Fly ash emissions from pulverized fuel boiler. Particle size distribution is not known but should be typical for other TVA plants and around 10 microns mass median diameter. Dust burden of effluent gases is around 3 to 6 g/Nm^3.

Type of Anti-Pollution Device

Electrostatic precipitators are used for control of particulate emissions. Precipitators are manufactured by Lodge-Cottrell. Design efficiency is 99%. Mechanicals of low efficiency (30%) are used preceding precipitator).

Reasons for Choice of Plant

This installation is of interest because it represents precipitator operation on a boiler burning high sulfur coal (around 3%) that produces a low resistivity ash.

Flue gas temperatures are lower than would be normal for coal with this amount of sulfur in coal. The precipitators represent a typical European type design with supported electrodes and high impact rappers.

Test Plan

Proposed tests would include the following:

1. Inlet and outlet dust burden.
2. Inlet and outlet particle size.

3. Electrical data from precipitators.
4. Fly ash analysis.
5. Coal analysis.
6. Gas analysis (SO_3, SO_2, NO_x, etc.).

Plant

Navajo Power Station, Salt River Project.

Type of Plant

Coal-fired electric power generating plant. 760 Mw capacity.

Emissions

Fly ash emissions from pulverized fuel boiler. No in-situ particle size measurements are available but would be expected to be approximately 6-10 microns MMD.

Type of Pollution Control Device

Electrostatic precipitators located upstream of the air preheater are used for particulate control. These precipitators were manufactured by the Western Precipitator Division of Joy Manufacturing Company.

Reasons for Choice of Plant

This plant is of interest because it represents the high temperature approach to solve the high resistivity dust problem typical of the low sulfur coals.

Test Plan

The proposed tests would include:

1. Inlet and outlet dust burden.
2. Inlet and outlet particle size distribution.
3. Electrical data from precipitators.
4. Fly ash analysis.
5. Coal analysis.

Plant

Widows Creek Plant of Tennessee Valley Authority.

Type of Plant

Coal-fired electric power generating plant.

Emissions

Fly ash from pulverized fuel boiler. Particle size of fly ash to dust control equipment averages around 20 microns. Very low efficiency precipitator is presently installed giving about 50% collection.

Type of Anti-Pollution Device

Wet scrubber of the turbulent contact type (TCA) is used for combined SO_2 and particulate removal. Four scrubbers are connected in parallel following the present precipitator. Gas volume to scrubbers is approximately 750 M^3/sec. Pressure drop accross scrubbers is 37 - 46 mmHg. Efficiency for SO_2 removal is expected to be 80%. Design exit dust burden is .04 g/Nm^3.

Reason for Choice of Plant

This plant is an example of a combined SO_2-particulate scrubber of the TCA type. It will be a new installation and should represent the latest design concepts.

Test Plan

The following tests are proposed:

1. Inlet and outlet dust burden.
2. Inlet and outlet particle size distribution.
3. Liquid flow rate.
4. Gas volume.

5. Pressure drop across scrubber.
6. pH of scrubbing fluid entering and leaving scrubber.
7. Gas analysis.
8. Fly ash analysis.

Plant

Sunbury Plant of Pennsylvania Power and Light Company.

Type of Plant

Anthracite coal-fired electric power generating plant. About 85 Mw capacity boiler.

Emissions

No data are available on character of emissions. Unit five burns low sulfur (.8%) coal and petroleum coke. Ash is reported to have high resistivity, hence the decision to go to fabric filters. Particle size of the dust is not known, but should be typical of PF fired boilers. Coal has rather high (30%) ash so inlet dust burden should be reasonably high.

Type of Anti-Pollution Device

Fabric filters are installed for particulate control. Each boiler has its own baghouse; each baghouse has 14 compartments arranged in 2 rows of seven compartments each. Each compartment contains 90 teflon-treated glass fiber bags. The total number of bags is 1260 per baghouse or 10,000 M^2 of filter area per baghouse. The gas flow is 100 M^3/sec at 160°C per baghouse.

Design efficiency is better than 99% with a guaranteed exit dust burden of .035 gm/M^3.

Reasons for Choice of Plant

This plant represents one of the few fabric filter dust collectors on large electric power boilers.

Test Plan

The following test data is proposed:

1. Inlet and outlet dust burden.
2. Inlet and outlet particle size distribution.
3. Pressure drop across filter.
4. Gas analysis.
5. History of fabric filter replacement.

Plant

Tampa, Florida plant of General Portland Cement Co.

Type of Plant

Dry process cement plant.

Emissions

No data are available about the dust emissions from the cement kiln of this plant. In general, kiln emissions would be bimodal with the large amount of the dust being relatively coarse (20 microns MMD). Smaller particle size dust is generally created by vaporization and subsequent condensation of the alkali in the feed. Dust loadings for this plant are expected to be in the vicinity of 40 g/Nm^3, although data are not available at this time.

Type of Pollution Control Device

An electrostatic precipitator is used to control emissions from the cement kiln. This precipitator is of the wire-weight-type construction. Design efficiency is around 99.8%.

Reason for Choice of Plant

This installation is relatively new and constitutes the present state of the art for control of cement kiln emissions.

Test Plan

Proposed tests would include the following:

1. Inlet and outlet dust burden.
2. Inlet and outlet particle size distribution.
3. Electrical data from precipitators.
4. Analysis of dust.

Novel Devices

Plant

Tampa plant of General Portland Cement Co.

Type of Plant

Dry process cement plant.

Emissions

Emissions from the klinker cooler have not been characterized from this plant. Inlet dust burden from the klinker cooler is estimated at around 14 g/Nm^3.

Type of Pollution Control Device

A gravel bed filter is used for control of klinker cooler emissions. The installation consists of two filters manufactured by Rexnord. Gas volumes are 30 M^3/sec and 90 M^3/sec at around 100°C. Exit dust burdens of 0.008 g/Nm^3 have been measured at the outlet of the filter. Pressure drop across the filter is around 15 - 19 mmHg. Each filter is preceded by a mechanical cyclone. System operates with a back flush and stir cycle for cleaning the filter.

Reason for Choice of Plant

This installation is one of the few gravel bed filters installed in this country. It has worked satisfactorily from a mechanical standpoint and should give data from which to extrapolate performance to other types of service.

Test Plan

Proposed tests would include:

1. Inlet and outlet dust burden.
2. Inlet and outlet particle size distribution to cover particle sizes down to 0.01 microns.
3. Pressure drop across filter.

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Plant

McWane Cast Iron Pipe Company

Type of Plant

Cast iron pipe shop.

Emissions

Iron is melted in a conventional iron cupola. Dust emissions vary widely in magnitude and composition depending upon the charge (type of scrap, etc.) and on the operating cycle. Emissions from cupolas vary in size depending upon the blast volume as well as the charge. Average particle size is expected to be about 1 micron MMD with a standard deviation of about 2. Dust burden to control device is around $3 g/Nm^3$.

Type of Anti-Pollution Device

Venturi - rod scrubber with a pressure drop of 280 cm water is used for dust emission control. Scrubber is manufactured by Environeering Inc. Efficiency is around 99%.

Reasons for Choice of Plant

This is a high energy scrubber operating on a fine fume.

Plant Cherokee Plant of Public Service Company of Colorado

Type of Plant

Coal fired electric power generating plant.

Emissions

Fly ash emissions from pulverized fuel electric power boiler. Dust burden from plant is around 6-10 g/Nm^3. Plant is equipped with mechanical cyclone so that dust burden leaving cyclone is around 1-2 g/Nm^3. Particle size of the dust is around 2-5 microns MMD.

Type of Anti-Pollution Device

The mechanical cyclone dust collectors are followed by a parallel arrangement consisting of electrostatic precipitator which receives 40% of the flue gases and a Turbulent Contact Absorber (TCA) scrubber which handles 60% of the flue gases. Scrubbers are operated open loop with no effort to remove SO_2, although about 40% reduction is achieved if fly ash is basic. Pressure drop across scrubbers is around 22 mmHg. No data are available on efficiency of the scrubber.

Reasons for Choice of Plant

There is considerable interest in TCA type scrubbers in this country. There is some evidence of relatively high collection efficiencies of small particles with moderate pressure drops. This is one of the few TCA scrubbers installed on electric power boilers.

Reason for Choice of Plant

The plant was selected because 1) the particle size of the dust is extremely fine; 2) very little data are available on control of emissions from glass plants and 3) the precipitator is of unusual design.

Test Plan

The following measurements are planned.

1. Inlet and outlet dust burden.
2. Inlet and outlet particle size analysis. Because of the small particle size of the dust, measurement techniques will concentrate on particles of less than 1 micron diameter.
3. Gas analysis.
4. Analysis of dust composition.
5. Precipitator electrical operating conditions.
6. Dust resistivity.

Test Plan

The following tests are proposed.

1. Inlet and outlet dust burden and gas volume.
2. Inlet and outlet particle size distribution.
3. Liquid flow rate.
4. Fly ash analysis.
5. Gas analysis at scrubber inlet and outlet.
6. Pressure drop across scrubber.
7. pH of scrubbing fluid entering and leaving scrubber.

Plant

Atlanta Plant - Owens-Illinois

Type of Plant

Plate glass manufacturing facility.

Emissions

Emissions from glass furnace. Gas volumes of around 20 M^3/sec are expected. Particle size of the effluent is extremely small with 95 to 97% less than 1 micron and 20 to 30% less than 0.2 microns. Inlet dust burden expected is around .2 to 1.4 g/Nm^3.

Type of Anti Pollution Device

This plant utilizies an electrostatic precipitator of the Nippon Air Filter Co. (NAFCO) design. Owen-Illinois is licensed in the U. S. for the precipitator and there are five plants in the U.S. of this type. Design efficiency is around 90-95%.

STATUS OF DEVELOPMENT OF METHODS FOR CONTROLLING NO_X EMISSIONS FROM STATIONARY SOURCES

In Accordance With Project B-8 Of Protocol Of 2nd Meeting Of The US/USSR Working Group On Stationary Source Air Pollution Control Technology

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1.0 INTRODUCTION

In the United States approximately 98% of nitrogen oxides emissions from stationary sources are generated in combustion processes. Consequently, the program for devel opment of nitrogen oxide control technology for stationary sources is oriented toward combustion sources. Particular emphasis is placed on coal combustion in utility and industrial boilers. Objectives for short-term solution of this problem include minimization of nitrogen oxide emissions via combustion modifications, identification of combustors with inherently low NO_x emissions, and development of flue gas cleaning methods. Primary effort is being exerted toward achieving the first of the objectives. At the present time, the most promising techniques for control of stationary combustion sources appear to be low excess air firing, flue gas recirculation, staged or off-stoichiometric combustion, and combustor re-design. The state-of-the-art in combustion modification is presented in Section 4.0 of this document. Research in fundamental chemistry of NO_x formation is reviewed in Section 2.0, and the next section briefly describes the current state of progress in clean fuel technology. In Section 5.0, flue gas cleaning methods are presented.

The majority of information contained in this paper was obtained from two recent documents prepared by the Control Systems Laboratory, National Environmental Research Center, U. S. Environmental Protection Agency. This group is responsible for research, development, and demonstration of processes and equipment required to control air pollution emissions from stationary sources.

2.0 CHEMISTRY OF NITROGEN OXIDES FORMATION AND DESTRUCTION

Fundamental combustion research studies have been undertaken to define the chemistry and physics of pollutant formation in combustion systems. The results obtained from small-scale, idealized combustion systems provide the fundamental understanding necessary to develop optimum NO_x control technology for larger scale application. There are three categories of these basic studies: chemistry of pollutant formation; aerodynamics or physical factors affecting pollutant formation; and mathematical simulation of pollutant formation in combustion systems.

NO_x may be formed during fuel combustion by fixation of atmospheric nitrogen (thermal NO_x) and/or oxidation of fuel-bound nitrogen. The chemistry of thermal NO_x formation may be described by the Zeldovitch reaction mechanism by which atomic oxygen reacts with molecular nitrogen to produce nitric oxide plus atomic nitrogen. This reaction has a high activation energy, and, consequently, is highly temperature dependent. Availability of atomic oxygen formed during high temperature combustion also must be considered. A second NO producing reaction consumes molecular oxygen and atomic nitrogen which is produced as a by-product of the first reaction. Rate constants for these and other reactions have been evaluated and experimental confirmation of the mechanism and kinetics is underway.

The second source of NO_x is conversion of nitrogen chemically bound in most solid and liquid fossil fuels. The mechanisms and chemistry involved are under investigation. The results published to date indicate that this chemistry is relatively independent of temperature and that ~50% of bound N is converted to NO while the remainder is converted primarily to nitrogen although other products may be formed. The degree of conversion to NO depends on available oxygen; thus NO formation can be reduced by combustion in a fuel-rich atmosphere. Experimental decomposition studies of selected pure N-containing compounds have shown that below 1000°C organic nitriles are formed as intermediates, while HCN results at temperatures above 1000°C. The major combustion product of heavy fuel oil is HCN while that of coal has not yet been determined. A second phase of this study will emphasize conversion of these primary decomposition products to nitrogen oxides.

Another related topic is the chemical reduction of NO_x in fuel-rich regions of the flame. Oxides of fuel-bound nitrogen are the pollutants under consideration here since thermal NO_x is minimized by control techniques in a fuel-rich atmosphere. Studies are in progress to define the chemistry of this type of reaction and to assess the applicability of catalysts to this phenomenon.

The physical phenomena involved in pollutant formation determine the actual conditions which exist within the flame zone. This zone is typically not of homogeneous composition, since in most burners fuel and air enter separately and mixing occurs within as a function of burner design. In one study the flow-field properties are being investigated in an ideal single burner combustor as a function of fuel and air inlet parameters. In an earlier program the relationship between flame quenching and NO_x formation was studied. Another EPA-funded experimental program is now underway to establish the role of flame interactions in multiple burner designs.

Several programs involving mathematical simulation of pollutant formation in combustion systems have been funded by EPA in recent years. The goal is to develop a general model for the chemical and physical processes of combustion based on results obtained from experimental studies. In one such study a computer technique is being developed to evaluate kinetics of numerous simultaneous combustion reactions and to screen the reaction set to determine key reactions. Presently, the model incorporates two simplified flow fields, the stream tube and the well-stirred reactor. Also under development is a computer code for rigorous solution of the Navier-Stokes flow equations and, in a separate study, the transition state theory for estimating kinetic rate constants.

In a related area of fundamental research, in-house work conducted by the Control Systems Laboratory is currently centered around combustion and emission characteristics of unconventional fuels of potential future importance, e.g., methanol. Equipment available on-site to conduct these studies includes a versatile 300,000 BTU per hour experimental furnace with provision for precise control of combustion parameters. The apparatus can also be employed to study combustion modification techniques in a variety of applications.

3.0 CLEAN FUELS

Most of the emphasis in clean fuel technology has been on development of desulfurization and deashing processes. Reducing the nitrogen content of fuels has received relatively little attention as a means of NO_x control.

Studies on coal composition and treatment relevant to potential nitrogen pollutants include surveys of chemical analyses for sulfur, nitrogen, and other species present in U. S. coals. Characterization of effluent and process streams in coal cleaning processes is being carried out to determine the fate of potential pollutants. In addition, high versus low temperature cleanup of raw fuel gas is being evaluated specifically for NO_x control.

For oil, again a survey of reported data describing fuel compositions is being conducted. For high nitrogen oils a research project is in progress dealing with the kinetics of simultaneous hydrodesulfurization and hydrodenitrogenation of liquid fuels. Of interest are the conditions under which the two types of reactions are mutually competitive or beneficial. The results of this study may have future application to the production of clean fuels from coal or shale oil.

4.0 COMBUSTION MODIFICATIONS

The chief thrust of NO_x control technology has been made in this area. The most promising combustion modification techniques include low excess air firing, flue gas recirculation, staged combustion, and combustor redesign. To date, application of these techniques to gas and oil-fired utility boilers has reduced NO_x emissions to levels as low as 70 ppm in some cases. In a 1970 field study it was found that, in general, 50-60% reduction can be achieved with gas- and oil-fired boilers. Application of these modifications to coal-fired boilers was less successful; operating problems resulted and less efficient NO_x reduction was achieved. Some short-term tests resulted in up to 50% reduction. Coal-fired units have since been emphasized, however, in current and future programs for NO_x control. Reduction of excess air level and staging combustion resulted in an average 40-50% reduction for a number of coal-fired boilers recently tested. For all types of boilers, burner and furnace design modifications have produced widely varying results in NO_x emissions. In general, however, tangential firing results in lowest pollutant emission in both controlled and uncontrolled cases. Table I presents ranges of NO_x emissions typical of various types of utility boilers at full and reduced loads, with and without combustion modifications, as compiled by Berkau (Ref. 1).

4.1 Overview of Modification Methods

A brief overview of the most important combustion modifications is presented below. A brief cost analysis is also included. Table II presents a summary of estimated investment costs for each technique newly installed as a function of fuel and plant size. The following load factors were used as the basis for these estimates:

TABLE I

NO_x EMISSIONS FROM CONTROLLED AND UNCONTROLLED BOILERS (1)

SOURCE		NO_x EMISSIONS, ppm			
		UNCONTROLLED		CONTROLLED	
FUEL	TYPE OF FIRING	FULL LOAD	REDUCED LOAD (2)	FULL LOAD	REDUCED LOAD (2)
GAS	General, all types	120-1500 (usually 120-900)	90-700	70-500	40-500
	Front-wall fired	130-1500	90 (25,40%)	100-500	40 (40%)
	Horizontally opposed	400-1500	200 (60%)	120-500	70 (60%)
	Tangential	<400	100 (70%)	70-160	no data available
OIL	General, all types	110-700	100-400 usually 140-320	110-450	120-340
	Front-wall fired	200-700 or higher	250 (25,50%)	170-320	170 (70%)
	Horizontally opposed	200-700	135 (50,75%)	170-320	150 (77%)
	Tangential	110-350	110 (50,100%)	100-200	120 (70%)
COAL	General, all types	300-900 (some as high as 1500)	200-800	200-500	150-400
	Front-wall fired	400-650	375 (70%)	350	300 (70, 80,
	Horizontally opposed	350-900	400 (75%)	350-450	150 (35%)
	Tangential	300-650	220 (80%)	200-500	150 (55, 80%)

(1) Source: Berkau, E. E., and D. G. Lachapelle, "Status of EPA's Combustion Program for Control of Nitrogen Oxide Emissions from Stationary Sources---September 1972", Presented at the Southeastern APCA Meeting, Raleigh, N. C., 19 September 1972.

(2) In each category, range is given for general firing types, minimum emissions reported are given for specific firing types. The % load at which minimum emission occurred is given in parentheses.

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Boiler Size (MW)	Annual Operation (hrs)
750 and 1000	6120
500	5620
250	3942
120	2190

Operating with low or minimum excess air has been practiced alone or in combination with other techniques in gas- and oil-fired utilities since the early 1960's. Application to coal-fired units is more complex, however. Up to 35% reduction in NO_x can be achieved on gas- and oil-fired boilers, and 49% reduction has been demonstrated on a commercial, tangentially-fired coal boiler (Ref. 1). The use of this technique is reported to increase boiler efficiency by 0.5-2% and even reduce maintenance and operating costs. While reductions in NO_x emissions as high as 70% have been observed in pilot scale coal-fired units, the reductions have been accompanied by reductions in carbon conversion efficiencies from 99.5% (20% excess air) to 96.2% (2% excess air) (Ref. 3).

Staged combustion and off-stoichiometric firing are similar techniques. The first involves burner operation with 90-95% of stoichiometric air admitted through the burners with the balance through "NO ports" located above the burners. The second modification involves firing lower sets of burners fuel-rich and upper burners fuel-lean or with air only. Emissions from gas-fired boilers have been reduced up to 72% with either or both of these techniques. Oil-fired units have achieved up to 55% reduction. Results from coal-burning units are in the area of 60% reduction, and are independent of firing method. Recent tests with an experimental coal-fired unit resulted in 50% reduction with very little loss in carbon conversion efficiency over conventional combustion. Staged combustion in combination with low excess air operation is the most common combustion modification employed.

Flue gas recirculation has been practiced for temperature control during reduced load operation for over twenty years. More recently it has been found effective for reducing thermal NO_x, as much as 70% for gas- and 50% for oil-fired units. Approximately 50% reduction of emissions from an experimental coal-fired boiler under conditions of 30% flue gas recirculation was recently reported (Ref. 3). However, significant reduction in carbon combustion efficiency was also observed. Investment costs for this modification are higher than for other techniques. Costs are expected to be particularly high in application to coal-fired boilers because of anticipated ash and slagging problems.

The effectiveness of water injection as a thermal NO_x control technique is due to flame temperature reduction. This method is especially applicable to gas-fired units equipped for standby oil-firing since the oil atomizers serve as convenient water injectors. While great NO_x reductions have been reported (67% for 250 MW gas-fired unit), loss in boiler efficiency is a related effect (1-6%).

4.2 Current Studies for Development of Combustion Modification Technology

Results of laboratory-, pilot-, and commercial-scale tests are being used to develop combustion modification technology. Several studies have been conducted to determine base-line NO_x emissions from uncontrolled combustion units fired by fossil fuels. The effects of various combustion parameters for NO_x emissions have been investigated on all levels. From these results, combustion modification techniques were evaluated and the most promising ones are currently being tested on commercial units.

Single gas burner design parameters and the influence of excess air were investigated to determine the relationship between combustion, aerodynamics, and air pollution emission characteristics for five burner types. The study showed that radial gas injection produces peak NO formation at 11% or less excess air, while peak concentrations occur at 22% or more excess air for axial gas injection. Changing from axial to radial injection results in greater NO emissions. Measured NO production also increases with increasing air preheat, although the magnitude of the increase depends on burner design.

Similar studies have been conducted with oil-fired burners. Flame zone flows and combustion characteristics were determined in a cold-flow, hot-fire single burner system. The experimental results were used to optimize burner designs capable of achieving 45-50% reduction in NO emissions compared to conventional oil-burners. Perpendicular combustor configurations were found to give higher NO_x emissions than coaxial configurations for all burners tested. In an evaluation of burner parameters for heavy oil-fired packaged boilers, staged combustion and flue gas recirculation resulted in 40% and 30-40% reduction in NO_x, respectively. These results will be further tested in two planned field units.

Single-burner studies of coal-fired burners were conducted to determine effective NO_x control techniques and to identify potential problem areas in boiler operation and loss of thermal efficiency. Results indicated that simultaneous control of excess air, air preheat, and load was the optimal approach for coal-fired boilers. After further tests at a pilot plant level, use of either staged combustion of delayed fuel/air mixing was recommended. In cases where implementation of this modification involved wide separation of the two sources of combustion air, severe problems with slagging and corrosion were reported. These did not occur if the design allowed for progressive mixing in individual burner zones. Field tests of staged combustion are planned.

Results of other pilot-scale studies are also available. Tests were conducted using a 500 lb/hr, 4-burner experimental coal-fired boiler. Reduction of excess air from 20 to 2% resulted in 70% reduction of NO_x emissions. However, carbon conversion efficiency was reduced from 99.5% at 20% excess air to 96.2% at 2% excess air. A 56% reduction was achieved with overfire air injections, and staged combustion gave 47% reduction with negligible reductions in carbon conversion efficiency. A reduction of NO_x emissions of 43% was measured at 31% flue gas recirculation, but carbon conversion efficiency was lowered from 99.5% to 95.9%.

These studies are being continued in another one-year study. The objective is to evaluate staged combustion and possibly overfire air injection on a 125 MW wall-coal-fired utility boiler. Long-term effects on unit operation and corrosion will also be studied.

Application of similar combustion modifications on a tangential-coal-fired 125 MW utility boiler is also under study. Evaluation and optimization of combustion technique employing overfire air ports will be performed. Again, long-term effects on unit performance and fireside corrosion will be studied.

5.0 FLUE GAS CLEANING

While flue gas cleaning is considered one of the near-term solutions for NO_x control, the development of gas cleaning methods is less advanced than that of combustion modification. There are several processes which are under investigation at the present time. Each of these is discussed briefly below.

5.1 Molecular Sieves

Molecular sieves are alkali metal alumino silicate crystals which dehydrate without collapse of the mineral structure. The pores in the remaining crystal lattice are of uniform molecular size and are capable of readsorption of water or other molecules. These materials can withstand repeated adsorption/desorption cycles. Selective adsorption capabilities are achieved via synthesis of pores of various sizes.

In a joint demonstration by EPA and the U. S. Army, a molecular sieve system retrofitted on a 50 ton per day nitric acid plant is being tested and evaluated. Start-up was scheduled for March, 1974. The objectives of this program are to determine the economics and operating characteristics under this type of application. The results could possibly lower NO_x performance standards for new nitric acid plants by a factor of 10 to 20; the current standard is 3 lb NO_x/ton of acid produced.

5.2 Catalytic Reduction of NO_x with Ammonia

The feasibility of reducing NO_x emissions from natural gas-fired boilers by catalyzed ammonia reduction is currently being demonstrated. The system is being tested on a pilot plant scale at the Valley Steam Plant, Los Angeles Department of Water and Power. The flue gas flow rate is 250,000 scfh.

The flue gas is contacted with ammonia and the gas mixture is then passed over a ceramic monolith coated with platinum. To date 85-90% reduction of NO_x has been achieved at 450° F and space velocities of 45,000 reactor volumes per hour. Continued parametric and long-term testing is planned.

5.3 Catalysts for Controlling NO_x Emissions

A recently completed one year program had as its objective the review and evaluation of domestic and foreign developments in catalytic NO_x abatement, determination of the technical and economic feasibility of such schemes, evaluation of their application to power generating plants, and identification of the most promising techniques for this particular application. Both selective NO_x reduction with ammonia and nonselective simultaneous NO_x-SO_x reduction with CO and H_2 appeared promising catalytic methods. A process for nitric oxide decomposition on platinum resulted in 50-60% NO_x removal in laboratory scale experiments. Platinum-based catalysts exhibited high activity at low temperatures for selective ammoniacal reduction of flue gases from plants fired with sulfur-free fuels. For the majority of existing power plants, however, SO_2 resistant, non-noble metal catalysts such as iron-chromium oxide and vanadia appeared more promising for this reaction. The simultaneous NO_x-SO_x reduction schemes on non-noble metal catalysts were a less feasible approach for existing plants but were favorably considered for new power plants.

5.4 Reduction of Nitric Oxide with Metal Sulfides

The reaction between a metal sulfide and nitric oxide to form metal sulfate and molecular nitrogen has been investigated by thermodynamic calculations and preliminary laboratory experiments. Seventeen different metal sulfides were tested and found to react with NO. Reaction temperatures ranged from 650°C for CdS to ~ 100°C for K_2S. Many candidates can be eliminated on the basis of typical flue gas temperatures being in the 150-175°C range. Those which merit further investigation at this time include the sulfides of calcium, barium, strontium, and iron. Following further screening studies, an economic analysis will be performed.

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6.0 SUMMARY

The current status of nitrogen oxide control from stationary sources in the United States has been reviewed. Since 98% of NO_x emissions in this category are generated by combustion processes, the emphasis of the program is on combustion sources, especially coal-fired boilers.

Methods of NO_x abatement under investigation include combustion modification, flue gas cleaning, and, to a limited extent, clean fuel technology. Some forms of combustion modification have been in use for a number of years and have been found effective for reduction of NO_x emissions from gas and oil-fired boilers. Application to coal-fired units is now in the development stages. Burner design parameters and fuel type also influence pollutant formation. Flue gas cleaning methods under government study are molecular sieves, catalytic reduction with ammonia and other chemicals, and reaction with metal sulfides. Demonstrations of many of these control methods are currently in progress or planned in field tests.

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